SW06 Shallow Water Acoustics Experiment Data Analysis

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LONG TERM GOALS

The long term goal of our shallow water acoustics work is to understand the nature of low frequency (10-1500 Hz) acoustic propagation and scattering in shallow water when strong oceanic variability in the form of fronts, eddies, boundary layers, and internal waves is present.

OBJECTIVES

Our primary objective this year was to continue the analysis of the data set collected by the SW06 experiment, with emphasis on internal wave effects, and model it with theory and numerical models. 3-D acoustics and oceanographic effects are of particular interest.

APPROACH

In performing the data analyses, we concentrated on the effects of realistic coastal nonlinear internal waves on acoustic propagation. We have finished publishing papers on the effects of truncated internal waves and curved internal waves, as well as internal wave effects on acoustic communications. We are now looking at internal wave directional spectra, and crossing internal wave trains. These latter effects impact the range and azimuthal variability of transmission loss and noise.

WORK COMPLETED/ACCOMPLISHMENTS

In the past year, we completed publication of papers on the effects of truncated internal wave ducts (JASA), curved internal wave ducts (IEEE JOE), and the effects of internal waves on acoustic communications (IEEE JOE). We have just submitted a JASA-EL paper on the first ocean observation of the "Horizontal Lloyd's Mirror," a 3-D acoustics effect that we had previously predicted.

RESULTS

The most spectacular result of our work over the last year was the observation of the "Horizontal Lloyd's Mirror" effect in the SW06 data set. Specifically, we observed both a direct and a reflected path coming from acoustic transmissions along a source/receiver track that was parallel to and close to a nonlinear internal wave train leading edge. In Figure 1, we see a direct path (first arrival) for all six modes recorded for the NRL 300 Hz source, and additionally a second arrival for modes four and five.

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This second arrival is the reflected ray coming from the source, hitting the internal wavefront and totally internally reflecting, and then proceeding to the receiver.

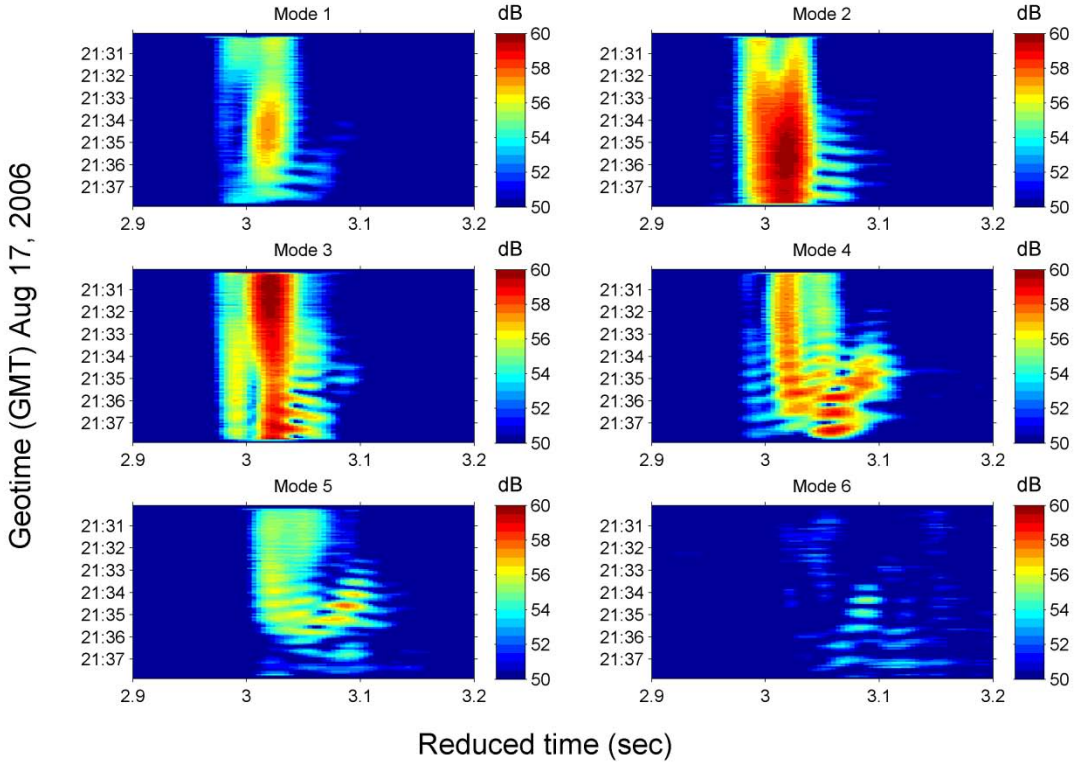

Fig. 1. Observation of Horizontal Lloyd's Mirror effect in SW06 300Hz transmissions

This is the second fully 3-D shallow water acoustic effect due to the oceanography (as opposed to bathymetric steering) that has been observed, the first being the horizontal ducting of sound between internal wave solutions. These 3-D acoustic effects are large (~6 dB for the Lloyd's Mirror and up to ~10 dB for the ducting), so that they make the case that one often needs to model the acoustics, and not just the coastal ocean, in a fully 3-D manner. These effects also might be exploitable for naval purposes.

IMPACT/APPLICATIONS

The impact of our experiment should be: 1) an increased understanding of the propagation of sound through the complicated coastal oceanography of the nonlinear internal wave field and 2) an eventual capability to model these effects for use in sonar performance prediction applications.

TRANSITIONS

One eventual transition of our analyses will be to ONR's Uncertainty DRI program, where the interest is in "the error bars" in ocean acoustic field and system performance prediction.

RELATED PROJECTS

The SWARM acoustics/internal wave study, the PRIMER acoustics/shelfbreak front study, and ASIAEX were direct predecessors of SW06, and examined some of the same acoustic scientific issues, only with far fewer measurement resources. The “Non-linear internal waves initiative” (NLIWI) is strongly related to our SW06 effort via the environmental support that the oceanographic moorings (and other PO measurements) provided. The just-completed QPE experiment, stressing acoustic and environmental uncertainty in a coastal environment, is also related.

PUBLICATIONS

[1] Y.T.Lin, T.F. Duda, and J.F. Lynch, “Acoustic mode radiation from the termination of a truncated nonlinear internal gravity wave duct in a shallow ocean area”, *J. Acoust. Soc. Am.* 124 (4), pp. 1752-1765 (2009).

[2] J. Lynch, Y.T Lin, T.F. Duda, and A.E. Newhall, “Acoustic ducting, reflection, refraction, and dispersion by curved nonlinear internal waves in shallow water”, *IEEE J. Oceanic Eng’g.* 35(1), pp. 12-27 (2010)

[3] Song, A.J., M. Badiey, A.E. Newhall, J.F. Lynch, H.A. Deferrari, B. Katsnelson, "Passive time reversal acoustic communications through shallow water internal waves", in press *IEEE J. Ocean. Eng.* (2010.)

[4] Badiey, M., B.G. Katznelson, Y.T. Lin, and J.F. Lynch, “Horizontal Lloyd’s mirror effect due to the interaction between acoustic waves and nonlinear internal waves.” Submitted to JASA-EL. (2010.)

PUBLICATIONS (non-refereed)

[1] Lynch, J.F., Duda, T.F., Lin, Y.T., and Newhall, A.E., “Nonlinear internal wave interactions with low frequency shallow water sound – what is left to do?”, proceedings of the SWAC09 Conference, Shanghai, PRC (2010).

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